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REMARKS

This amendment is responsive to the Official Action dated May 8, 2003. Claims 1-20 were pending in the application.

No claims were allowed.

By way of this amendment, the Applicant has amended claims 1-6, 8-11, 13, 15, 16 and 18, and added new claims 21-28.

Accordingly, claims 1-28 are currently pending.

Petition for Extension of Time:

A petition for an extension of the response time from August 8, 2003 to October 8, 2003 is attached.

Claim Rejections under 35 USC §102(b):

Claims 1-20 were rejected under 35 USC §102(b) as being anticipated by Jewel USP 5,719,894. The Examiner states that Jewell discloses a VCSEL having an active region 110 comprising a plurality of quantum wells 126,128 wherein the gain of each quantum well operates quasi-independently at different temperatures.

Applicant respectfully disagrees and requests reconsideration.

The VCSEL emission wavelength is solely determined by the thickness of its resonant cavity, the region between the top and bottom mirrors. The two mirrors are made highly reflective, to create a very high Q resonant cavity, one in which light bounces back and forth between the mirrors hundreds of times before leaving the cavity. This forces the bouncing photons to pass through the very thin active region in the cavity hundreds of times, increasing their chances of stimulating radiative transitions in the very thin active region. For a high Q cavity, the cavity emission peak is very narrow, that is, the range of wavelengths of the photons that can bounce back and forth between the mirrors hundreds of times is very narrow and is commonly called the cavity peak. In order for the bouncing photons to have a chance of stimulating emission in the active region to induce lasing, that active region must have transition energies, whose corresponding stimulated photon wavelengths match the cavity

peak. The range of the transition energies, and of the corresponding photon wavelengths, is commonly called the gain peak of the active region. It is also usually a relatively narrow peak, although somewhat broader than the cavity peak. In most VCSELs, the best active regions comprise one or more Quantum Wells (QWs), separated by barrier layers.

The gist of Jewell et al (5,719,894) is how to compose active region QWs and barriers, whose gain peaks match the cavity peaks, at "extended" wavelengths in the vicinity of 1.3 µm, in VCSELs formed on GaAs substrates. Prior to Jewel, many in the industry had difficulty obtaining operation of surface emitting lasers at wavelengths greater than 1300nm. The entire focus of Jewel is to obtain lasing at the desired wavelength.

> *"Thus, although the prior art therefore describes a variety of techniques useful in forming long-wavelength lasers on GaAs substrates, it fails to provide any specific example of a viable such structure, nor does it provide any range of parameters within which viable such structures may be fabricated, nor does it teach the construction of a viable such structure. Some references suggest the possibility of 1.3 .µm lasers on GaAs substrates, but provide unrealistic parameters and are several years old or more.*
>
> *SUMMARY OF THE INVENTION*
>
> *It is therefore an object of the present invention to provide an active region having a quantum well structure which may be utilized in lasers grown on GaAs substrates and which will provide an emission wavelength of at least 1.3µm." Column 6, lines 1 - 16.*

While both Jewel and the present invention focus on long wavelength VCSEL, the objectives of each are different. The present invention focuses on obtaining a stable level of emission over an extended temperature range without the use of external cooling devices.

In this regard, the present invention describes a VCSEL structure wherein the active region is provided with multiple quantum wells, each having a unique construction optimized to have a peak gain at a wavelength offset from the cavity wavelength for a given temperature. During operating, each quantum well will function independent from the others based on its construction and the junction temperature. Therefore, as the junction temperature increases,

the gain peak of each quantum well will independently move from shorter to longer wavelengths relative to the cavity wavelength (See Figs. 1a-1c and 7a).

The main issue that our application addresses and Jewell et al (5,719,894) does not address is the fact that although both the cavity peak and the gain peak wavelengths change with temperature, at rates given in nm/°C, the gain peak changes at a much faster rate (about 5-6 times faster) than the cavity peak does. As a result, the gain peak moves relative to the cavity peak as a function of temperature. As is illustrated in the attached Figure 1, the net consequence is that the gain peak and the cavity peak may overlap over some temperature range, centered at Temp2, but at, or below, a lower temperature Temp1 and at, or above, a higher temperature Temp3 they no longer overlap and lasing ceases. The typical temperature range of overlap may be no larger than a few 10's of degrees, depending on the actual width of the gain peak. If the active region comprises 2 or more identical QWs (3 in Figure 1), their gain peaks coincide and move together. This arrangement does not improve the temperature range of operation, but can allow for greater net gain in the VCSEL (since the gain peaks add constructively) to overcome the need for some designed-in greater losses. **The invention(s), described in our application, address and ameliorate the above problem of limited temperature range of operation in VCSELs.** The gist of our application will be reiterated below after a brief aside.

Gain peaks also undergo a secondary change as temperature changes. With increasing temperature, gain peaks become somewhat broader and shallower. This effect is also shown to an exaggerated amount in Figure 1. This secondary effect can be ignored, to first order, in the solutions as described by our application, or it can also be compensated for with a slightly more sophisticated approach to the solutions.

The essence of the solutions described in our application is composing an active region, which comprises 2 or more QWs, separated by barrier layers, such that the gain peaks of the QWs are slightly staggered, or offset from each other, in wavelength, as is shown in the attached Figure 2. Then, as is also shown in Figure 2, as temperature changes, at least one of the gain peaks overlaps the cavity peak, over a much larger temperature range, including Temp1 and somewhat below it and including Temp2 and somewhat above it. Secondary claims in the application then describe the various ways the QWs and/or barriers can be

engineered to achieve the staggering of the gain peaks. Thereafter, the application also describes how the QWs and barriers can be further engineered to compensate for the secondary effect so as to maintain a constant gain over an extended temperature range.

While Jewel discloses the use of multiple quantum wells with regard to Figs. 9a and 10a, it is understood by the reader that Jewel uses multiple quantum wells to increase optical gain, and not to provide extended temperature range.

> *"The advantage of having multiple quantum wells is that for a given electron-hole density, the optical gain is increased." Column 35, lines 39-41.*

There is no indication or even a suggestion that the multiple quantum wells have different gain peaks or that the gain peaks are progressively offset to obtain a stable output over an extended temperature range. Jewel simply indicates that there are multiple quantum wells and that they may be slightly different. For example, based on the teaching of Jewel that multiple quantum wells would increase optical gain, Jewel might teach an arrangement as shown in the attached Exhibit B, where three nominally identical quantum wells are formed in a VCSEL. Even though slightly different, all three are formed with a similar gain peak, and all three would operate uniformly together (not quasi independent with temperature as shown in Fig. 1). Once again, we point out (and Jewel points out) that the primary focus of the invention is to obtain stimulated emission at a wavelength above 1300nm.

> *"For brevity, individual combinations are not discussed. But, it should be appreciated that this application contemplates any combination which increases the emission wavelength to 1.3 μm or above for a GaAs substrate" Column 35, lines 62-67.*

While Jewel does indicate that the quantum wells may be different, he does not elaborate on how they are different or why they are different. More importantly, there is no teaching or suggestion in Jewel to construct the quantum wells with different gain peaks nor that the quantum wells in Jewel would operate differently from each other at different temperatures.

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Accordingly, one can not assume that the Jewel quantum wells would operate quasi-independently at different temperatures.

With regard to claims 2-20, the Examiner further indicates that Jewel discloses the underlying claimed concepts of varying the well thickness or barrier thickness, etc. As claimed in the present invention, these features refer to a progressive change from one well to another well within the same device to provide a means for obtaining different gain peaks for each well. However, as understood within the context of Jewel, Jewel's discussion of changes in well thickness, well composition, and barrier thickness relates to a uniform change in the construction of all wells and all barriers in the same device in order to achieve stimulated emission at 1300nm. For example, with regard to claim 2, the claim recites an embodiment where the well thickness varies from "well to well" within the device (See Applicant Fig. 9). The Examiner refers to Jewel Column 16, lines 16-34 and column 17, lines 19-29, and column 19, lines 26-46 (reproduced below).

> *"FIG. 1 illustrates a plot of the room-temperature (300 K) peak transition energy v. quantum well thickness for several In concentrations of $In_yGa_{1-y}As$ strained quantum wells on a GaAs substrate with GaAs barriers. FIG. 1 is read in conjunction with the table in FIG. 3. As may be seen, there are eight curves, each corresponding to a respective reference numeral 10, 12, 14, 16, 18, 20, 22 and 24. Curve 10 represents a 33% concentration of In in the type III semiconductor material comprising the $In_y Ga_{1-y}As$ strained quantum well. This corresponds to y having a value of 0.33. As may be seen, the peak transition energy decreases as the quantum well thickness increases. For a In concentration of 0.33, the critical thickness (CT) is 71.9 Å. At the CT, the critical accumulated strain (CAS) is 170 Å %, the peak transition energy is 1.118 eV and the peak transition wavelength is 1.109 μm. The CAS in Å % is the CT in A multiplied by the strain in %. It should be appreciate that the CT discussed with regard to FIGS. 1 and 2a are determined by equation 1." Column 16, lines 16-19.*

> *"Prior reports such as Coleman's, disclose edge-emitting lasers grown and fabricated with strained InGaAs quantum wells. The quantum wells had 25% In, for which the CT is ~ 105 Å. Lasers with 100 .ANG. quantum wells showed excellent threshold characteristics and reliability. It has been found that by increasing the thickness of the quantum wells to 125 Å., initial current thresholds were reasonable but the current thresholds doubled after testing for*

> *times on the order of a few thousand hours. The increase in thickness resulted in a high density of atomic misfit dislocations and associated problems." Column 17, lines 19-29.*
>
> *"One period of the $(InAs)_2\ (GaAs)_1$ superlattice, where y=0.67, is about 8.5Å. and the calculated CT is 26.2 Å. Thus, three periods are just below the CT. It should be appreciated that two periods yield a much thinner quantum well with a much shorter peak transition wavelength. For a $(InAs)_3\ (GaAs)_1$ superlattice, where y=0.75, one period is about 11.3Å. and the calculated CT is 22 Å. Thus, two periods slightly exceed the calculated CT by 0.6Å. This superlattice structure is illustrated in FIG. 4b. For such thin quantum wells, even the thickness of the well is uncertain since exclusion of one GaAs monolayer outside of the well would reduce the well thickness by about 3Å. In both the 0.67 and 0.75 examples, a 3Å reduction in thickness brings the quantum well below the CT. It should be appreciated that the critical thickness for a superlattice may actually exceed the CT. Gourly et al. found that the critical thickness for a superlattice was measurably larger, by more than 20%, than the critical thickness for a ternary alloy having the same average composition. Column 19, lines 26-46.*

However, it is clear from the text above, that these comparisons in well thickness and other characteristics refer to comparisons of the effects of discrete changes in the wells to overall emission wavelength and that they do not teach using a combination of different thickness or a progressive change in thickness (or some other characteristic) from well to well within the same device to provide extended temperature range (different gain peaks).

As noted above, Jewel is not concerned with extended temperature range, the primary focus is on obtaining lasing at the desired wavelength.

Reconsideration and allowance of claims 1-20 is respectfully solicited.

The Applicant has also entered new claims 21-28 which are also believed to define patentable subject matter.

Accordingly, claims 1-28 are believed to be in condition for allowance and the application ready for issue.

Corresponding action is respectfully solicited.

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PTO is authorized to charge any additional fees incurred as a result of the filing hereof or credit any overpayment to our account #02-0900.

Respectfully submitted,

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